Global Hydrology Resource Center

Data User Guide

International Space Station (ISS) Lightning Imaging Sensor (LIS) datasets

Introduction

The International Space Station (ISS) Lightning Imaging Sensor (LIS) datasets were collected by the LIS instrument mounted on the ISS and are used to detect the distribution and variability of total lightning occurring in the Earth's tropical and mid-latitude regions. These datasets consist of near-real time and non-quality controlled science and background data, while the final quality controlled science and background datasets are continually being added as manually reviewed. This data collection can be used for severe storm detection and analysis, as well as for lightning-atmosphere interaction studies. The LIS instrument makes measurements during both day and night with high detection efficiency. The data are available in both HDF-4 and netCDF-4 formats, with corresponding browse images in GIF format and summary images in PNG format.

Citations:

There are a total of six citations provided below with two for the NRT data, two for the non-quality controlled data, and two for the quality controlled data. For each of these, the citations are divided between the Science Data and the Background data.

NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data Citation

Blakeslee, Richard J. 2019. NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data [indicate subset used]. Dataset available online from the NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/LIS/ISSLIS/DATA106

NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds Citation

Blakeslee, Richard J. 2019. NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds [indicate subset used]. Dataset available online from the NASA

Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/LIS/ISSLIS/DATA206

Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data

Blakeslee, Richard J. 2019. Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data [indicate subset used]. Dataset available online from the NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/LIS/ISSLIS/DATA107

Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds

Blakeslee, Richard J. 2019. Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds [indicate subset used]. Dataset available online from the NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/LIS/ISSLIS/DATA207

Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data

Blakeslee, Richard J. 2020. Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data [indicate subset used]. Dataset available online from the NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/LIS/ISSLIS/DATA108

Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds

Blakeslee, Richard J. 2020. Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds [indicate subset used]. Dataset available online from the NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/LIS/ISSLIS/DATA208

Keywords:

GHRC, NASA, International Space Station, ISS, Lightning Imaging Sensor, LIS, lightning, lightning density, NRT, NQC, QC

Mission/Instrument Description

The LIS instrument was placed on the ISS in February 2017 as a hosted payload on the Space Test Program-Houston (STP-H5) mission managed by the Department of Defense Space Test Program. The STP-H5 had a 2-year mission, which was recently extended due to a successful end of primary mission review in June 2019. The position of LIS on the ISS

allows for latitudinal measurement extending poleward up to 54°. The goals of LIS on the ISS are to determine the relationship between clouds, lightning, and precipitation, to extend the global lightning climatology record particularly in the mid-latitudes, to examine the physics of lightning discharge, to examine the uses of lightning for improving severe weather warnings, and to estimate lightning nitrogen oxides to improve air-quality modeling. The ISS LIS also serves as an intercomparison data set for the Geostationary Lightning Mapper (GLM). More information about the ISS LIS is available in Blakeslee et al., 2016.

Two LIS instruments were originally designed by the Lightning Team at the Global Hydrology and Climate Center and were manufactured at the Marshall Space Flight Center (MSFC) in Huntsville, Alabama. One was installed on the Tropical Rainfall Measuring Mission (TRMM) satellite and used on orbit from 1999 to 2015. The other LIS instrument, designed as a flight spare, was installed on the ISS in February 2017 and continues to operate. The long-term TRMM LIS measurements significantly contributed to several mission objectives by providing global lightning and thunderstorm climatology datasets. The ISS LIS instrument has a greater range of measurement, due to the ISS orbital inclination of 51.6 degrees versus TRMM's orbital inclination of approximatily 35 degrees. These mid-latitude observations allow for the measurement of front-related lightning events.

The Lightning Imaging Sensor contains a staring imager which is optimized to locate and detect lightning with a storm-scale resolution of 4 km at nadir (directly below the instrument) increasing to 8 km at limb (at the edge of measurement region), with a swath width of about 550 km of the Earth's surface. The Field-of-View (FOV) is sufficient to observe a point on the Earth or a cloud for about 90 seconds, which is adequate timing to estimate the lightning flash rate of many storms. The push broom, matrix array consisting of 128 x 128 detectors allows for each earth location to be observed continuously every 2 milliseconds for about 90 seconds. The ISS LIS instrument records the time of occurrence, radiant energy, and location of each lightning event.

LIS uses a wide FOV expanded optics lens with a narrow-band filter centered at 777 nm in conjunction with a high-speed charge-coupled device detection array. A Real-Time Event Processor (RTEP) is used to determine when a lightning flash occurs even within bright, sunlit clouds. Weak lightning signals that occur during the day can be hard to detect due to background illumination. Lightning is being detected by the RTEP comparing light observed versus the background and if the optical energy exceeds the background, it is considered an event and not noise. The RTEP removes the background signal, thus enabling the system to detect these weak lightning signals with about a 90% detection efficiency. More information about the LIS instrument is available in the Earth Observations: Lightning Imaging Sensor (LIS) Micro Article, the TRMM LIS PMM webpage, Blakeslee et al., 2016, Christian et al., 1992, Blakeslee et. al., 2014, and Christian et al., 1999.

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Data Characteristics

The International Space Station (ISS) Lightning Imaging Sensor (LIS) datasets contain measured lightning flashes from March 1, 2017, onward as the LIS instrument continues to collect data in near-real time. The data are in both HDF-4 and netCDF-4 formats, with corresponding browse images for the science data in GIF format and summary images in PNG format. There are currently four types of data within this dataset:

- NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data
- NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds.
- Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data
- Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds
- Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data
- Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds

Near-real time (NRT) data are available within two minutes of observation. These data are appropriate for applications requiring low latency data. NRT data and browse images age off the server and are not a static archived data collection. The non-quality controlled (NQC) data are created daily and are more complete than the NRT data. These data have not been reviewed to assure data quality and are more appropriate for science and operational applications. The final quality controlled (QC) dataset files are continually being added as manually reviewed. As these QC data files are added to the dataset, the corresponding NQC data are being removed.

The ISS LIS data files contain orbital data, as well as a browse image showing the data plotted on a map. Summary browse images are also included. These summary files show the combined data from the browse images summarized for each season and month of the year. A link to the browse image collection is on the dataset landing pages. These data files were processed by the validated V1.0 algorithm. V2.0 of the QC data are coming soon.

The data have been back-processed so that all data files have the new algorithm applied as of June 2019.

The science data are at a Level 2 processing level, while the background data are at a Level 1B processing level. More information about the NASA data processing levels are available on the EOSDIS Data Processing Levels webpage. Table 1 shows the characteristics of the data files.

The background data are for use with the science data. One form of intercomparison of the LIS geolocation and lightning events involves using the LIS background data to determine the surrounding storm structure of the lightning events. Because the radiant properties from land and water differ, where the LIS instrument points can be verified by coastline discrimination in the background data. Users, therefore, need both the science data and the background data to interpret the lightning events. In addition, the LIS background cloud-field data are matched to appropriate visible and near-infrared satellite data.

Table 1: Data Characteristics

Characteristic	Description
Platform	International Space Station (ISS)
Instrument	Lightning Imaging Sensor (LIS)
Projection	Centroid
Spatial Coverage	N: 54.0, S: -54.0, E: 180.0, W: -180.0
Spatial Resolution	4-8 km
Temporal Coverage	March 1, 2017 - ongoing
Temporal Resolution	NRT: 2 minutes
Sampling Frequency	Every 2 milliseconds over ~90 seconds
Parameter	lightning, lightning density
Version	V1.0
Processing Level	1B (Background Data) and 2 (Science Data)

File Naming Convention

The International Space Station (ISS) Lightning Imaging Sensor (LIS) datasets have the following naming convention: (See Table 2 for variable descriptions)

NRT Data: ISS_LIS_<TT>_V<v.v>_<YYYYMMDD>_<hhmmss>_NRT_<xxxxx>.[hdf|nc]
NRT Browse: ISS_LIS_BR_V<v.v>_<YYYYMMDD>_<hhmmss>_NRT.gif
Summary Browse: YYYY[_xxx].png

NQC and Final QC Data: ISS_LIS_<TT>_V<v.v>_<YYYYMMDD>_[NQC|FIN]_xxxxx.[hdf|nc]
NQC and Final QC Browse: ISS_LIS_BR_V<v.v>_<YYYYMMDD>.gif

Table 2: File naming convention variables

Variable	Description
TT	Type of file: SC = science BG = background
v.v	Processing algorithm version number used to create the dataset
YYYY	Four-digit year of data
MM	Two-digit month
DD	Two-digit day
hh	Two-digit hour in UTC
mm	Two-digit minute in UTC
ss	Two-digit second in UTC
NRT	Near-Real Time data
[NQC|FIN]	NQC: Non-Quality Controlled data FIN: Final Quality Controlled data
xxxxx	5-digit ISS LIS orbit number
[hdf|nc]	hdf: HDF-4 format nc: netCDF-4 format
.gif	Graphics Interchange Format
[_xxx]	Monthly and seasonal browse summary files, names of months and seasons have various lengths
.png	Portable Network Graphics files

Data Format and Parameters

The International Space Station (ISS) Lightning Imaging Sensor (LIS) datasets are obtained from measurements made by the LIS onboard the ISS. These datasets contain science and background data from March 1, 2017, onwards as LIS continues to collect data in near-real time. The science dataset consists of single orbit files with lightning count and lightning flash density measurements, while the background data, also organized as 1 file per orbit for NQC/QC and as 1 file every 2 minutes for NRT, can be used to check and verify geolocation calculations and monitor the stability of the LIS instrument. Lightning flash

centroid density is the number of lightning flash centroids per kilometer squared while the events are in the LIS instruments field-of-view. The flash centroid is the single latitude/longitude point representing the entire flash. The flash centroids are typically the focus for various efforts, particularly the browse imagery. The flashes are based on the initial 'event' observations that are clustered into 'groups' that are, in turn, clustered into flashes. Additional details can be found in the ATBD.

The NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds, Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds, and Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Backgrounds datasets consists of background data. These background data were created approximately one to two seconds apart and provide the scene on which lightning can be plotted. When using the IDL code to read the files, an entire orbit of background data can be displayed in a simple animation to allow a quick way to see if interesting cloud systems, such as hurricanes or frontal systems were within the field-of-view. Data within the background files align with the same parameters in the science files are not described in further detail in this guide, so as not to repeat the same tables.

The NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data, Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data, and Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data are stored in HDF-4 and netCDF-4 format files. Tables 3 - 12 describe each parameter in each ISS LIS provisional data file. More information about these parameters can be found in Christian, et al., 2000.

NRT data are available within two minutes of observation. These data are appropriate for applications requiring rapid use of lightning data. NQC data are standard products that are created daily. The NQC data are more complete than the NRT data, and both datasets lack manual review for improved data quality. The QC data have had specific quality control steps applied to ensure that all bad data are flagged. The QC datasets are most appropriate for scientific research and publications.

These ISS LIS datasets are considered **validated data**, which means the algorithm has undergone a series of enhancements to improve overall data quality compared to the earlier provisional data set. Browse images for these LIS data are available in GIF format. Daily browse images were created showing the ascending and descending orbits, location of lightning, and statistical data. **Please note that the 'day' in the browse imagery and the 'day' in the science data are defined differently.** Browse imagery begins at 00Z and ends 24 hours later, i.e. from midnight to midnight, while the science data day starts during the first orbit of the GMT day and ends during the last orbit of the GMT day.

The science datasets contain orbit data and a browse image showing the data plotted on a map. Summary browse images are also included in PNG format. These summary files show the data from the browse images, summarized for each season and month of the year. The browse images can be located using the link on the dataset landing page.

Table 3: **Orbit Summary Attribute Parameter Field Descriptions**. The orbit summary consists of summarized orbit attributes.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
configuration_code	orbit_summary_configuration_code	Code indicating which code configuration scenario was used when processing the data	short	-
end_longitude	orbit_summary_end_longitude	Longitude boundary defining the end of this orbit	float	Degrees East
GPS_start	orbit_summary_GPS_start	Orbit start time for the Global Positioning System	double	s
id_number	orbit_summary_id_number	The number of this orbit, where the orbit count starts with LIS installation on ISS	int	-
inspection_code	orbit_summary_inspection_code	Code indicating which problem scenarios were checked by the QA inspector	short	-
one_second_address	Orbit_summary_one_second_address	Address of the first element in the one-second data	int	-
one_second_count	orbit_summary_one_second_count	Number of one-second records	int	-
point_data_address	orbit_summary_point_data_address	Point data child record number	short	-
point_data_count	orbit_summary_point_data_count	Number of point data records	short	-
start_longitude	orbit_summary_start_longitude	Longitude boundary defining the start of this orbit	float	Degrees East
summary_image_address	orbit_summary_summary_image_address	Summary GIF image record number	short	-
summary_image_count	orbit_summary_summary_image_count	Number of summary GIF images	short	-
TAI93_end	orbit_summary_TAI93_end	TAI93 end time	double	Seconds since 1993-01-01 00:00:00.000
TAI93_start	orbit_summary_TAI93_start	TAI93 start time	double	Seconds since 1993-01-01 00:00:00.000
UTC_start	orbit_summary_UTC_start	UTC start time	char	-

Table 4: **One Second Field Descriptions**. The one-second fields show the status of the LIS instrument in a series of one-second intervals.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit

alert_summary	one_second_alert_summary	Bit masked summary of alert flags. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
attitude_quality_flag	one_second_attitude_quality_flag	one second granule attitude quality flag	int	-
boresight_threshold	one_second_boresight_threshold	one second granule threshold estimate	byte	-
ephemeris_quality_flag	one_second_ephemeris_quality_flag	one second granule ephemeris quality flag	int	-
event_count	one_second_event_count	One second granule event count	short	-
external_alert	one_second_external_alert	Bit masked status of external factors. Bit1 is the Least Significant Bit (LSB) bit1=1:Warning_Satellite_within_SAA_Model1 bit2=1:Warning_satellite_within_SAA_Model2 bit3=1:Warning_direct_solar_reflection_possible_within_FOV bit4=1:Indifferent_TRMM_Microwave_imager_ on bit5=1:Indifferent_Precipitation_Radar_on bit6=1:Indifferent_Visible_Infrared_Scanner_on bit7=1:Indifferent_Clouds_and_Earth_Radiant_Energy_System_sensor_on bit8: (reserved)	byte	-
instrument_alert	one_second_instrument_alert	bit masked status of instrument. Bit1 is the Least Significant Bit (LSB) bit1=1:Fatal_instrument_off bit2=1:Indifferent_instrument_command_executed bit3=1:Fatal/Warning_FIFO_buffer_overflow bit4=1:Warning_threshold_set_very_high bit5=1:Fatal_instrument_warning_up bit6=1:Warning_improper_operating bit7=1:Fatal_Packet_gap	byte	-

		bit8=1:Warning_data_handling_problem		
noise_index	one_second_noise_index	One second granule noise index	byte	%
platform_alert	one_second_platform_alert	Bit masked status of platform. Bit1 is the Least Significant Bit (LSB) bit1=1:Warning_no_attitude_or_ephemeris_quality_flags_available bit2=1:Fatal_ephemeris_not_available bit3=1:Warning_ephemeris_possibly_inaccurate bit4=1:Fatal_attitude_not_available bit5=1:Warning_attitude_possibly_inaccurate bit6=1:Fatal_clock_not_available bit7=1:Warning_clock_possible_inaccurate bit8: (reserved)	byte	-
position_vector	one_second_position_vector	One second granule platform coordinates	float	m
processing_alert	one_second_processing_alert	Bit masked status of processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1:Warning_QA_inspector_warning_flag bit2=1:Fatal_QA_inspector_fatal_flag bit3=1:Fatal_data_too_garbled_for_software_to _read bit4=1:Fatal_data_set_too_large_to_process bit5=1:Fatal/Warning_unforseen_software_error_caused_improper_reporting_of_data bit6=1:Warning_grouping_algorithm_buffer_limitation_Problem bit7=1:Warning_viewtime_algorithm_failure_to_ accurately_determine_FOV bit8: (reserved)	byte	-
solar_vector	one_second_solar_vector	Unit vector from center of earth to sun in ECR coordinates	float	-
TAI93_time	one_second_TAI93_time	Whole second value starting before and continuing beyond one orbit	double	Seconds since 1993- 01-01 00:00:00.00 0

thresholds	one_second_thresholds	Values of the instrument threshold settings for each 256 count background interval	byte	-
transform_matrix	one_second_transform_matrix	Components of transform from pixel plane boresight coordinates to ECR coordinates of boresight and pixel plane	float	-
velocity_vector	one_second_velocity_vector	One second granule platform velocity	float	m/s

Table 5: **Point Summary Parameter Field Descriptions**. These measurements allow a user to quickly get to point datasets, such as addresses (the data file addresses of parameters) and counts (the total number of point data in the data file).

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
area_address	point_summary_area_address	Area record number	int	-
area_count	point_summary_area_count	Number of areas	int	-
bg_address	point_summary_bg_address	Background image summary record number	int	-
bg_count	point_summary_bg_count	Number of backgrounds	int	-
event_address	point_summary_event_address	Event record number	int	-
event_count	point_summary_event_count	Number of events	int	-
flash_address	point_summary_flash_address	Flash record number	int	-
flash_count	point_summary_flash_count	Number of flashes	int	-
group_address	point_summary_group_address	Group record number	int	-
group_count	point_summary_group_count	Number of groups	int	-
parent_address	point_summary_parent_address	Parent record number	int	-
vt_address	point_summary_vt_address	View time granule record number	int	-
vt_count	point_summary_vt_count	Number of view time granules	int	-

Table 6: **View time Parameter Field Descriptions**. The View time Parameter fields show view time parameters that are required in order to determine flashing rates on the Earth.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
alert_flag	viewtime_alert_flag	Reflects the status of the instrument, platform, external factors, and processing algorithms. Bit1 is the Least Significant Bit (LSB). bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
approx_threshold	viewtime_approx_threshold	The threshold of instrument corresponding with grid cell position, proxied from solar zenith angle at a time halfway between the start and end time	byte	-

effective_obs	viewtime_effective_obs	Time of observation of the grid cell, adjusted by the percentage of area in the grid cell within the FOV	float	s
-	viewtime_lat	Latitude of the center of the grid cell of dimensions 0.5 deg x 0.5 deg	float	Degrees North
location	viewtime_location	Latitude/Longitude of the center of the grid cell of dimensions 0.5 deg x 0.5 deg	float	degrees
-	viewtime_lon	Longitude of the center of the grid cell of dimensions 0.5 deg x 0.5 deg	float	Degrees East
TAI93_end	viewtime_TAI93_end	TAI93 whole second when location last within FOV	int	Seconds since 1993-01-01 00:00:00.000
TAI93_start	viewtime_TAI93_start	TAI93 whole second when the location was first within FOV	int	Seconds since 1993-01-01 00:00:00.000

Table 7: **Bg_Summary Parameter Field Descriptions.** The Bg_Summary parameter fields show parameters that describe the details of the background data, although they are stored separately due to the large file sizes.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	bg_summary_address	Background image number within the orbit	int	-
boresight	bg_summary_boresight	Latitude/Longitude location of the center pixel (63, 64)	float	degrees
corners	bg_summary_corners	Latitude/Longitude location of corner pixels	float	degrees
-	bg_summary_lat	Background image boresight latitude	float	Degrees North
-	bg_summary_lon	Background image boresight longitude	float	Degrees East
TAI93_time	bg_summary_TAI93_time	TAI93 time of the background image	double	Seconds since 1993-01-01 00:00:00.000

Table 8: **Area Parameter Field Descriptions**. The area parameter field descriptions show data associated with each area identified during the orbit. An area is defined as a contiguous region on the surface of the Earth that has produced lightning during a single orbit of the LIS instrument.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	lightning_area_address	Area record number	int	-

alert_flag	lightning_area_alert_flag	Bit masked status of the instrument, platform, external factors, and processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
approx_threshold	lightning_area_approx_threshold	The estimated value of the 8-bit threshold for the area determined from background level or solar zenith angle	byte	-
child_address	lightning_area_child_address	Area child record number of 1st flash in a sequential list	int	-
child_count	lightning_area_child_count	Area child record number of flashes	int	-
cluster_index	lightning_area_cluster_index	Pixel density metric; higher numbers indicate the area is less likely to be noise	byte	%
delta_time	lightning_area_delta_time	The time between first and last event that compose the area	float	s
density_index	lightning_area_density_index	Spatial density metric; higher if area geolocated in a region of high lightning activity	byte	-
footprint	lightning_area_footprint	Area footprint extent	float	km^2
grandchild_count	lightning_area_grandchild_count	Number of groups in area	int	-
greatgrandchild_count	lightning_area_greatgrandchild_count	Number of events in area	int	-
grouping_sequence	lightning_area_grouping_sequence	Time sequence of area used when grouping algorithm is applied	int	-
grouping_status	lightning_area_grouping_status	End status of the area	byte	-
-	lightning_area_lat	Latitude radiance-weighted centroid	float	Degrees North
location	lightning_area_location	Latitude/Longitude radiance-weighted centroid	float	Degrees
-	lightning_area_lon	Longitude radiance-weighted centroid	float	Degrees East
net_radiance	lightning_area_net_radiance	Sum of event radiances composing this area	float	$uJ/sr/m^2/um$
noise_index	lightning_area_noise_index	Signal-to-signal plus noise ratio	byte	%
oblong_index	lightning_area_oblong_index	Eccentricity of the area	float	-
observe_time	lightning_area_observe_time	Duration of observation of the region where the area occurred	short	s
parent_address	lightning_area_parent_address	Area parent record number	int	-
TAI93_time	lightning_area_TAI93_time	TAI93 times of 1st event in area	double	Seconds since 1993-01-01

				00:00:00.000

Table 9: **Event Parameter Field Descriptions**. The Event Parameter fields show data that are associated with events recorded during the ISS orbit. An event is defined as a single pixel exceeding the background threshold.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	lightning_event_address	Event record number	int	-
alert_flag	lightning_event_alert_flag	Bit masked status of the instrument, platform, external factors, and processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
amplitude	lightning_event_amplitude	Uncalibrated optical amplitude reported by instrument (a 7-bit digital count)	byte	-
approx_threshold	lightning_event_approx_threshold	The estimated value of the 8-bit threshold for the area determined from background level or solar zenith angle	byte	-
bg_radiance	lightning_event_bg_radiance	Background radiance associated with the pixel at the time of the event	short	uJ/sr/m^2/um
bg_value	lightning_event_bg_value	Level of background illumination (16-bit) at time of the event	short	-
bg_value_flag	lightning_event_bg_value_flag	Background (bg) radiance has been 0: estimated from sza 1: interpolated from bgs	byte	-
cluster_index	lightning_event_cluster_index	Pixel density metric; higher numbers indicate area is less likely to be noise	byte	%
delta_time	-	The time between first and last event that compose the area	float	s
density_index	lightning_event_density_index	Spatial density metric; higher if area geolocated in a region of high lightning activity	byte	-
footprint	lightning_event_footprint	Area footprint extent	float	km^2
glint_index	lightning_event_glint_index	The angle between the line of sight vector and direct solar reflection vector	byte	degrees
grouping_sequence	lightning_event_grouping_sequence	Time sequence of area used when grouping algorithm is applied	int	-
grouping_status	-	End status of the area	byte	-
-	lightning_event_lat	Latitude radiance-weighted centroid	float	Degrees North
location	lightning_event_location	Latitude/Longitude radiance-weighted centroid	float	degrees
-	lightning_event_lon	Longitude radiance-weighted centroid	float	Degrees East

noise_index	lightning_event_noise_index	Signal-to-signal plus noise ratio	byte	%
observe_time	lightning_event_observe_time	Duration of observation of the region where the area occurred	short	s
parent_address	lightning_event_parent_address	Area parent record number	int	-
radiance	lightning_event_radiance	Event calibrated radiance	float	uJ/sr/m^2/um
sza_index	lightning_event_sza_index	Event solar zenith angle	byte	degrees
TAI93_time	lightning_event_TAI93_time	TAI93 times of 1st event in area	double	Seconds since 1993-01-01 00:00:00.000
x_pixel	lightning_event_x_pixel	Event CCD pixel column	byte	-
y_pixel	lightning_event_y_pixel	Event CCD pixel row	byte	-

Table 10: **Group Parameter Field Descriptions**. The Group Parameter fields show data associated with each group identified during the orbit. A group is defined as one or more simultaneous events that register in adjacent pixels in the focal plane array, which may consist of only one or many events.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	lightning_group_address	Group record number	int	-
alert_flag	lightning_group_alert_flag	Bit masked status of the instrument, platform, external factors, and processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
approx_threshold	lightning_group_approx_threshold	The estimated value of the 8-bit threshold for the group determined from background level or solar zenith angle	byte	-
child_address	lightning_group_child_address	Group child record number	int	-
child_count	lightning_group_child_count	Group child record count	int	-
cluster_index	lightning_group_cluster_index	Pixel density metric; higher numbers indicate group is less likely to be noise	byte	%
density_index	lightning_group_density_index	Spatial density metric; higher if - group geolocated in a region of high lightning activity	byte	-
footprint	lightning_group_footprint	Group footprint size	float	km^2
glint_index	lightning_group_glint_index	Group solar glint cosine angle	byte	degrees

grouping_sequence	lightning_group_grouping_sequence	Time sequence of group used when grouping algorithm is applied	int	-
grouping_status	lightning_group_grouping_status	Group grouping status	byte	-
-	lightning_group_lat	Latitude radiance-weighted centroid	float	Degrees North
location	lightning_group_location	Latitude/Longitude radiance-weighted centroid	float	degrees
-	lightning_group_lon	Longitude radiance-weighted centroid	float	Degrees East
noise_index	lightning_group_noise_index	Signal-to-signal plus noise ratio	byte	%
oblong_index	lightning_group_oblong_index	Eccentricity of the group	float	-
observe_time	lightning_group_observe_time	Length of observation of the region where the group occurred (view time approximation at group centroid)	short	s
parent_address	lightning_group_parent_address	Group parent record number	int	-
radiance	lightning_group_radiance	Group calibrated radiance	float	uJ/sr/m^2/um
TAI93_time	lightning_group_TAI93_time	TAI93 time of all events in group	double	Seconds since 1993-01-01 00:00:00.000

Table 11: **Flash Parameter Field Descriptions.** The flash parameter fields show data associated with each area or flash identified during the orbit. A flash is defined as one to multiple pulses that occur in the same storm cell within a specific time and distance corresponding to several related groups in a limited area.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	lightning_flash_address	Flash record number	int	-
alert_flag	lightning_flash_alert_flag	Bit masked status of the instrument, platform, external factors, and processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
approx_threshold	lightning_flash_approx_threshold	The estimated value of the 8-bit threshold for the flash determined from background level or solar zenith angle	byte	-
child_address	lightning_flash_child_address	Address of 1st group in a sequential list	int	-
child_count	lightning_flash_child_count	Flash child record count	int	-

cluster_index	lightning_flash_cluster_index	Pixel density metric; higher numbers indicate flash is less likely to be noise	byte	%
delta_time	lightning_flash_delta_time	The time between first and last group that composes the flash	float	s
density_index	lightning_flash_density_index	Spatial density metric; higher if flash geolocated in a region of high lightning activity	byte	-
footprint	lightning_flash_footprint	Flash footprint size	float	km^2
glint_index	lightning_flash_glint_index	Flash solar glint cosine angle	byte	degrees
grandchild_count	lightning_flash_grandchild_count	Flash grandchild record count	int	-
grouping_sequence	lightning_flash_grouping_sequence	Time sequence of flash used when grouping algorithm is applied	int	-
grouping_status	lightning_flash_grouping_status	Flash grouping status	byte	-
-	lightning_flash_lat	Latitude radiance-weighted centroid	float	Degrees North
location	lightning_flash_ocation	Latitude/Longitude radiance-weighted centroid	float	degrees
-	lightning_flash_lon	Longitude radiance-weighted centroid	float	Degrees East
noise_index	lightning_flash_noise_index	Signal-to-signal plus noise ratio	byte	%
oblong_index	lightning_flash_oblong_index	Eccentricity of the flash	float	-
observe_time	lightning_flash_observe_time	Duration of observation of the region where the flash occurred	short	s
parent_address	lightning_flash_parent_address	Flash parent record number	int	-
radiance	lightning_flash_radiance	Flash calibrated radiance	float	$uJ/sr/m^2/um$
TAI93_time	lightning_flash_TAI93_time	TAI93 times of 1st event in flash	double	Seconds since 1993-01-01 00:00:0 0.000

Table 12: **Raster Images Parameter Field Descriptions.** These parameters consist of an image plot of the orbit and the associated color table.

HDF Field Name	netCDF Field Name	Description	Unit
raster_image	raster_image	Raster image plot of the orbit in each file. It is included for a quick examination and manual identification of specific orbits of interest.	-
raster_image_color_table	raster_image_color_table	the color table for raster image plot of the orbit in each file	-

Algorithm

The LIS software produces lightning data and corresponding background data from instrument measurements. The software decodes, filters, clusters, and then outputs the data in HDF-4 and netCDF-4 files. Table 13 shows the steps needed to create the data products. More detailed information about LIS software is available in Christian et al., 2000.

The original beta algorithm data were released in August 2017. Several improvements have been made since, especially corrections of false lightning detections and timing issues. These improved provisional algorithm data products became publicly available as of June 18, 2018. As of June 2019, the validated algorithm data products became publicly available. The V1 QC data became publicly available in February 2021.

Table 13: Software Tasks

Step	Task
1	ISS to native lightning/background format converting
2	Pixel-based filtering
3	ISS to native ephemeris format converting
4	Ephemeris filtering
5	Geo-Locating
6	Determining LIS view time
7	Flash clustering
8	Flash-based filtering
9	Area clustering
10	Area-based filtering
11	HDF-4 and netCDF-4 file creation

Quality Assessment

In February 2021, V1 of the final QC data for ISS LIS Science and Backgrounds became publicly available. These data are continually being added as manually reviewed. As these QC files are added to the dataset, the corresponding NQC data are being removed. V2 of these data are coming soon.

In June 2019, the validated algorithm was completed and was used to update these data. This update included corrections to the background images due to packet loss, correctly calculates the footprint size of flashes, reports the radiance values, and corrected partial orbit files. This algorithm will be updated as validation continues and the data will be reprocessed. All prior publications of these data (e.g., beta and provisional) are superseded with this release.

In June 2018, these data were updated to a new version (p0.2) containing fixed geolocation issues identified in the p0.1 version files distributed in January 2018. The p0.1 data contained fixed timing issues found in the original provisional data files (p0) released in December 2017.

The original beta algorithm was used to produce ISS LIS data products during August - December 2017. The provisional algorithm was implemented in December 2017. This

improved provisional algorithm provides corrections of false lightning detection and timing issues. With the latest P0.2 upgrades, geolocation issues have also been addressed.

The calibration of LIS data is split into two different categories: an absolute radiometric calibration of the LIS sensor performed pre-launch, and an in-orbit calibration of the LIS sensor performed once operating on the ISS. The in-orbit calibration is extremely important for the interpretation and utilization of the data. LIS data are also validated by verifying the true amplitude, location, and time of detected lightning events. Verification of background image alignment, image brightness, and remote adjustment of threshold settings are performed to minimize false alarms and maximize lightning detection.

The geolocation of lightning events and background data involves many facets of the LIS program testing processes. The orientation of the Charged Coupled Device (CCD) with respect to the LIS alignment cube was determined from an Euler angle analysis of precise yaw and pitch maneuvers of the LIS sensor head assembly during radiometric calibration of LIS. The orientation of the LIS alignment cube to the spacecraft-based attitude reference frame was then determined. The alignment correction is simply a constant angular measure applied to space attitude. Given real-time updates of the spacecraft ephemeris and attitude data, accurate LIS geolocation is determined. Detection efficiency ranges from 69% near noon to 88% at night.

One form of intercomparison of the LIS geolocation and lightning events involves using the LIS background image. Because the radiant properties from land and water differ, where the LIS instrument points can be verified by coastline discrimination in the background data. In addition, the LIS background cloud-field data are matched to appropriate visible and near-infrared satellite data.

For quality assurance, all events, groups, flashes, and areas are assigned data quality tags, indicating whether the data are associated with high noise rates, solar glint, or randomly spaced events, or if the data were positioned relative to events with high lightning probabilities. In addition, the LIS data files are manually inspected for irregularities in the dataset. The data files that fail specific quality assurance tests are flagged. The high-level quality flags assigned to each LIS data file include instrument, platform, external, and processing/algorithm alert flags. These data are assigned a 'class' designation with values of 'Good files', 'Good files containing zero events', 'Files unreadable with the IDL code', 'Files with known anomalies', and 'Missing files'. Files that are flagged as 'Files unreadable with the IDL code', 'Files with known anomalies', and 'Missing files' are not distributed. A list of undistributed files is under construction.

The LIS instrument exists in a noisy space environment. It also responds to a number of optical signals, not all of which are necessarily lightning related. A significant amount of software filtering goes into the science data, which maximizes both the detection efficiency and the confidence level so that each datum is a lightning signal and not noise. Each lightning event in a file is tagged with four low-level quality indicators, and each data file is assigned four high-level flags that are designed to notify potential users of possible irregularities in the data. An automated process is used to tag each optical event with a set

of four numbers that indicate the relative likelihood that the event was produced by lightning, as opposed to solar glint, energetic particles in the Van Allen radiation belt, or electronic noise. Table 14 lists and describes the low-level data tags. In addition, the LIS data files are manually inspected for irregularities. The data files that fail specific quality assurance tests are flagged. The high-level quality flags assigned to each LIS data file are described in Table 15. Orbit files from the LIS data can come in five classes, which are described in Table 16. More information about the quality assessment of these data are available in Christian et al., 2000.

Table 14: Low-level quality tags

Tag	Name	Description
1	Non-noise Probability	The probability that the event is not caused by random noise or energetic particles
2	Solar Glint Factor	A number that indicates the likelihood that the event was caused by direct reflected solar radiation
3	Event Rate Ratio	A number that represents the ratio of 'accepted' events to the raw detected events during a one-second period at the time of the event
4	Probability Density	A number that indicates whether the event is geolocated in the vicinity of other events that are likely to be lightning

Table 15: High-level quality tags

Tag	Description
1	Instrument Alert Flag
2	Platform Alert Flag
3	External Alert Flag
4	Processing and Algorithm Alert Flag

Table 16: Classes in LIS orbit files

Class	Description
1	Good files: These files contain good data. Be forewarned that occasionally the instrument/platform fatal flags may be intermittently set in some of these orbits. In these orbits, about 50 of the one-second data flags are set to fatal or wanting. Unless these flags are contiguous, the data are considered to be good data. The vast majority of the LIS files are in this category.
2	Good files containing 0 events: These are a subset of the good data files, except no lightning events were observed. This subset is listed separately because even though the data files contain no lightning events, there is a dummy data set of length 1 inserted into these files to prevent problems in reading the files. All fields in the dummy point data are set to 0. The view time data are good and are necessary when computing climatological lightning rates. These files are not listed separately anywhere. It is up to the user to determine how to work with them. There are only about 10 of these data files per year.
3*	Files unreadable with the IDL code: These files contain good orbit data, but the LIS instrument wasn't working because it was turned off. The one-second data can be read in, but the lightning data has a length of 0 that causes some software to crash. It should be noted that there is no lightning information in these files since the instrument was turned off.
4	Files with known anomalies: These files have been observed to have some sort of anomaly, such that lightning data are available for only part of the orbit. The one-second data flags are set correctly in these files.

5*	Missing files: Some data files are simply not produced. The causes of these missing data files vary, but are mainly due to LIS instrument outages due to sun acquisition maneuvers, Leonid meteor stream, etc.

*Because they contain no useful science data, Class 3 and Class 5 data files are not distributed.

Software

These LIS data are available in both HDF-4 and netCDF-4 formats. Panoply can be used to easily view the netCDF-4 files and HDFView can be used to easily view the HDF-4 files. Also, the ISS LIS Lightning Flash Location Quickview using Python and GIS Data Recipe and the ISS LIS Lightning Flash Location Quickview using Python 3.0 and GIS can be used to plot these LIS data. Lastly, the LIS/OTD software package, developed by the LIS team, can be used to read the data files. IDL code is also available to plot these data. Specific system and platform requirements are spelled out in Chapter 3 of the LIS/OTD software manual. For more information, please review Chapter 3 of the Software manual.

Known Issues or Missing Data

These NRT data are available within two minutes of observation. There may be missing data due to the nature of real-time data transmission. The NRT data are appropriate for applications requiring low latency data. NRT data are not retained for archival and age off the GHRC servers. The NQC data are created daily and are more complete than the NRT data. Due to this, these data are more appropriate for science and operational applications.

The most appropriate data to use for scientific research and publications are the final quality controlled data. Version 1 of the final QC science and background datasets are continually being added as manually reviewed. As these QC files are added to the dataset, the corresponding NQC data are being removed. Anomalies that were detected in the ISS LIS datasets during QC procedures are documented in the ISS LIS Anomalies documentation. Version 2 of these data are coming soon.

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Related Data

Two LIS instruments were originally built. One was previously installed on the Tropical Rainfall Measuring Mission (TRMM) satellite platform and operated on-orbit from 1998 - 2015. The TRMM LIS and ISS LIS instruments are identical. Therefore, the TRMM LIS dataset is considered a related dataset. Higher level lightning data products exist at GHRC that included TRMM LIS data in their construction, but as of June 2019, all higher level products only include the TRMM LIS data. Any products containing LIS data, whether from TRMM or ISS, can be located using the HyDRO 2.0 search tool with the search term "LIS". The following datasets are LIS data onboard the TRMM satellite:

TRMM Lightning Imaging Sensor (LIS) Science Data
(http://dx.doi.org/10.5067/LIS/LIS/DATA201)

TRMM Lightning Imaging Sensor (LIS) Backgrounds
(http://dx.doi.org/10.5067/LIS/LIS/DATA101)

LIS 0.1 Degree Very High Resolution Gridded Lightning Climatology Data Collection
(http://dx.doi.org/10.5067/LIS/LIS/DATA306)

LIS/OTD Gridded Lightning Climatology Data Collection
(http://dx.doi.org/%2010.5067/LIS/LIS-OTD/DATA311)

Contact Information

To order these data or for further information, please contact:

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